

Organization of the Nervous System, Basic Functions of Synapses, "Transmitter Substances"

Sensory Part of the Nervous System

Most activities of the nervous system are initiated by sensory experience exciting sensory receptors, whether visual receptors in the eyes, auditory receptors in the ears, tactile receptors on the surface of the body, or other kinds of receptors. Input to the nervous system is provided by sensory receptors that detect such sensory stimuli as touch, sound, light, pain, cold, and warmth. This information enters the central nervous system (CNS) through peripheral nerves and is conducted immediately to multiple sensory areas in (1) the spinal cord at all levels; (2) the reticular substance of the medulla, pons, and mesencephalon of the brain; (3) the cerebellum; (4) the thalamus; and (5) sensory areas of the cerebral cortex.

"Somesthetic"

The Sensory Receptors

Sensory receptors are specialized structures located at the peripheral terminations of the afferent nerves.

Functions of the sensory receptors :

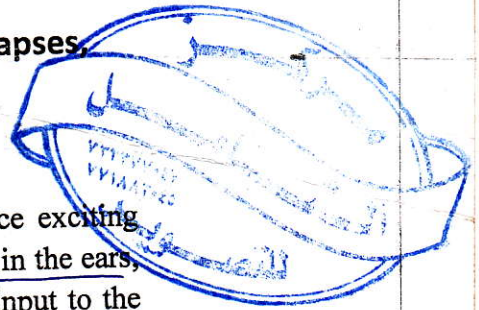
- 1- Receptors are transducers i.e they transform different forms of energy into neural signals or nerve impulses. A sensory receptor detects an arriving stimulus and translates it into action potential that can be conducted to CNS.
- 2- They inform the CNS about various changes occurring inside and outside the body. The nerve impulses generated at the receptors are transmitted to the CNS via afferent neurons where they give rise to various sensations and initiate appropriate reflex movements and adjustments of various body functions.

Properties of receptors :

1-Specificity : The first question that must be answered is, how do two types of sensory receptors detect different types of sensory stimuli? The answer is, by "differential sensitivities." That is, each type of receptor is highly sensitive to one type of stimulus for which it is designed and yet is almost nonresponsive to other types of sensory stimuli. For example :

- Cold and warm receptors are more sensitive to thermal form of energy.
- Touch and pressure receptors are more sensitive to mechanical form of energy.
- Rods and cones in retina are most sensitive to light waves or electromagnetic waves but are almost completely nonresponsive to normal ranges of heat, cold, pressure on the eyeballs, or chemical changes in the blood.

Muller's law of specific nerve energy : each receptor gives one type of sensation irrespective of the method of stimulation



Muller's law
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Classification of receptors according to their specificity :

- ① A : Mechanoreceptors : which detect mechanical compression or stretching of the receptor or of tissues adjacent to the receptor
- *touch (tactile) receptors, these are present in the skin e.g. free nerve endings, Merkel's discs, Meissner's corpuscles, hair end organs around the hair follicle, and pacinian corpuscles and Ruffini's end organs
 - *baroreceptors of carotid sinus and aortic arch.
 - *proprioceptors present in the muscle and tendons eg: muscle spindle and Golgi tendon organ.
- ② B : Thermoreceptors : these respond to thermal stimulus in the form of changes of temperature eg; cold and warm receptors of the skin. They include :
- *Krause's corpuscles for cold.
 - *Ruffini's corpuscles for warmth.
- ③ C : Chemoreceptors : these respond to chemical form of energy. They include :
- *receptors of aortic and carotid bodies (oxygen level in the arterial blood)..
 - * osmoreceptors in hypothalamus (osmolality of the body fluids). *supraoptic nuclei*
- ④ D : Nociceptors : these are free nerve endings that perceive pain sensation. They are stimulated by any form of energy provided it causes damage to the tissues.
- ⑤ E: Electromagnetic receptors : these are stimulated by electromagnetic waves as light like rods and cones in retina.

2-Excitability

All sensory receptors have one feature in common. Whatever the type of stimulus that excites the receptor, its immediate effect is to change the membrane electrical potential of the receptor. This change in potential is called a receptor potential. A receptor potential which is large enough to produce an action potential is called a generator potential.

Because of the relative large size of the pacinian corpuscle it can be isolated and studied. The tip of the central fiber inside the capsule is unmyelinated, but the fiber becomes myelinated shortly before leaving the corpuscle to enter a peripheral sensory nerve. When a small area of the terminal fiber is deformed by compression of the corpuscle, the ion channels opens in the membrane, allowing positively charged sodium ions to diffuse to the interior of the fiber. This creates increased positivity inside the fiber, which is the "receptor potential." The receptor potential in turn induces a local circuit of current flow that spreads along the nerve fiber. At the first node of Ranvier, the local current flow depolarizes the fiber membrane, which then sets off typical action potentials that are transmitted along the nerve fiber toward the CNS.

3-Rate of discharge

When receptors are stimulated, the frequency of their discharge is related to the intensity of the stimulus. The greater the intensity, the higher the frequency of discharge of impulses along the afferent nerve fibers (Weber-Fechner Law).

weber-fechner law

4-Adaptation

Adaptation means a ^{تخفيف}decline in the response of receptors as a result of constant stimulus application. That is, when a continuous sensory stimulus is applied, the receptor responds at a high impulse rate at first and then at a progressively slower rate until finally the rate of action potentials decreases to very few or often to none at all.

Classification of receptors according to rate of adaptation :

- 1- Slowly adapting receptors (tonic receptors) :
these receptors continue to discharge along the afferent nerve and transmit information to the brain for many hrs as long as the stimulus is present. They keep the brain constantly informed about the status of the body and its relation to its surroundings. Eg; pain receptors continue to discharge to protect the body against injurious agents, muscle spindle to maintain body posture, baroreceptors to maintain normal blood pressure. Because the slowly adapting receptors can continue to transmit information for many hours, they are called tonic receptors.
- 2- Rapidly adapting receptors (rate or phasic receptors) :
These discharge impulses along the afferent nerve at the moment of stimulation, followed by rapid decline of rate of discharge in spite of the maintained stimulation of the receptor. They react strongly while a change is actually taking place, therefore, these receptors are called rate receptors, movement receptors, or phasic receptors. Examples include touch receptors and pacinian corpuscles.

5- Coding of sensory information

Modality of Sensation—The "Labeled Line" Principle

Each of the principal types of sensation like pain, touch, sight, sound is called a modality of sensation. Each nerve tract terminates at a specific point in the CNS, and the type of sensation felt when a nerve fiber is stimulated is determined by the stimulated receptor and by the point in the nervous system to which the fiber leads. For instance, if a pain fiber is stimulated, the person perceives pain. Likewise, if a touch fiber is stimulated by electrical excitation of a touch receptor or in any other way, the person perceives touch because touch fibers lead to specific touch areas in the brain. Similarly, fibers from the retina of the eye terminate in the vision areas of the brain, fibers from the ear terminate in the auditory areas of the brain, and temperature fibers terminate in the temperature areas.

- This specificity of nerve fibers for transmitting only one modality of sensation is called the labeled line principle.

Basic Functions of Synapses (Transmitter Substances)

The central nervous system contains more than 100 billion neurons. A typical neuron of a type found in the brain motor cortex is composed of 3 major parts :

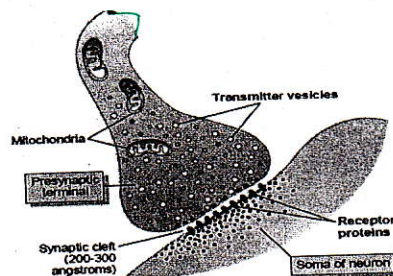
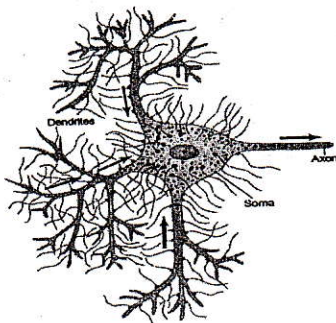
- The soma which is the main body of the neuron.
- A single axon which extends from the soma into a peripheral nerve that leaves the SC.
- The dendrites which are great number of branching projection of the soma extending about 1mm into the surrounding areas of the cord.

Incoming signals enter this neuron through synapses located mostly on the neuronal dendrites, but also on the cell body. Conversely, the output signal travels by way of a single axon leaving the neuron. Then, this axon has many separate branches to other parts of the nervous system or the peripheral body.

Physiologic Anatomy of the Synapse

The synapse : is the site of contact between the axon terminals of one neuron (presynaptic neuron) and the soma or dendrites of another neuron (post synaptic neuron).

As the presynaptic fiber approaches the postsynaptic neuron, it divides into many branches which end in small knobs or buttons called presynaptic terminals lie on the surfaces of the dendrites and soma of the motor neuron, about 80 to 95 per cent of them on the dendrites and only 5 to 20 per cent on the soma.



The presynaptic terminal is separated from the postsynaptic neuronal soma by a synaptic cleft having a width usually of 200 to 300 angstroms. The terminal has two internal structures important to the excitatory or inhibitory function of the synapse: the transmitter vesicles and the mitochondria. The transmitter vesicles contain the transmitter substance that, when released into the synaptic cleft, either *excites* or

~~inhibits~~ the postsynaptic neuron. The mitochondria provide adenosine triphosphate (ATP), which in turn supplies the energy for synthesizing new transmitter substance. ATP

Synaptic transmission :

When an action potential spreads over a presynaptic terminal, depolarization of its membrane causes calcium channels open and allow large numbers of calcium ions to flow into the terminal. When the calcium ions enter the presynaptic terminal, it is believed that they exert an attractive force that draws the transmitter vesicles toward the presynaptic membrane and causes the release of their transmitter substance into the cleft after each single action potential. The membrane of the postsynaptic neuron contains large numbers of receptor proteins to which the transmitter binds and triggers either opening or closure of specific ligand-activated ion channels resulting in electric changes called postsynaptic potentials which leads to either excitation or inhibition of the postsynaptic neuron. ACh

If the neurotransmitter released into the synaptic cleft is excitatory as acetyl choline, noradrenaline, dopamine it combines with the receptors of the post synaptic membrane. This opens gates for Na^+ ions and increases the membrane permeability to Na^+ , while closes K^+ channels and decrease their efflux. The increase in Na^+ ion inflow decreases the potential difference between the outside and the inside of the membrane. The post synaptic neuron is excited. A state of partial depolarization in the post synaptic membrane is called excitatory post synaptic potential (EPP).

If the neurotransmitter released into the synaptic cleft is inhibitory as gamma amino butyric acid (GABA) and glycine, it combines with the receptors of the post synaptic membrane. This opens gates for Cl^- ions and increases the membrane permeability to Cl^- and also allows K^+ to move out of the cell. This increases the negativity of the membrane potential i.e hyperpolarization, the postsynaptic neuron is inhibited. A state of partial hyperpolarization in the post synaptic membrane is called inhibitory post synaptic potential (IPP).

inhibitory postsynaptic potential

Summation of post synaptic potentials :

A single presynaptic impulse causes a reduction in the resting memb potential which cause a state of partial depolarization of postsynaptic neuron which is called excitatory postsynaptic potential (EPP), or hyperpolarization which is called inhibitory postsynaptic potential (IPP). To reach the firing level the EPP must undergo summation in order to raise the excitability o of the postsynaptic neuron to threshold firing level needed for generation of a propagated action potential.

Types of summation :

5/6/21 **Spatial summation** : occurs when several pre synaptic fibers are excited at the same time. Excitatory PSP or inhibitory PSP summate and raise or decrease the excitability of the post synaptic neuron to the threshold value and result in the discharge or inhibition of post synaptic neuron.

$$120 + (80 \times 2)$$

3

Temporal summation : occurs when a single presynaptic neuron is repetitively stimulated. Resulting EPSPs or IPSPs are summated.

factors affecting synaptic transmission :

1-pH of blood :

alkalosis increase excitability while acidosis decrease excitability.

2-Lack of oxygen : decrease excitability.

3-Hypoglycemia decrease excitability and decrease synaptic transmission as glucose is the only fuel used by the brain.

4-Drugs like theophylline and caffeine increase synaptic transmission while analgesics and hypnotics decrease transmission.

Types of synapses :

Chemical synapses : Almost all the synapses used for signal transmission in the CNS of the human being are chemical synapses. In these, the first neuron secretes at its nerve ending synapse a chemical substance called a *neurotransmitter* and this transmitter in turn acts on receptor proteins in the membrane of the next neuron to excite the neuron or inhibit it.

Chemical synapses always transmit the signals in one direction: that is, from the neuron that secretes the transmitter substance, called the *presynaptic neuron*, to the neuron on which the transmitter acts, called the *postsynaptic neuron* (the principle of one-way conduction).

Electrical synapses :

are characterized by direct open fluid channels that conduct electricity from one cell to the next. Most of these consist of small protein tubular channels called *gap junctions* that allow free movement of ions from the interior of one cell to the interior of the next. Electrical synapses are rare in CNS.

Unlike chemical synapses, electrical synapses always transmit signals in both directions.

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"Theophylline"
white crystalline powder used as a oral agent for reactive airway diseases such as asthma. The drug has a narrow therapeutic index and toxicity to this agent marked by gastrointestinal upset, tremor, cardiac arrhythmias and other complications, is common in clinical practice. Other drugs for reactive airway diseases, such as inhaled beta-agonists and inhaled steroids, are often prescribed instead of Theophylline to avoid toxicities.

مركز القدس للخدمات الطلابية

SOMATIC SENSATIONS

Somatic sensations include those from the skin and deep tissues eg; joints, ^٢ muscles and bones, and are mediated by afferent somatic nerves. These senses are in contradistinction to special senses, which mean specifically vision, hearing, smell, taste. *in compare*

Classification of somatic sensations

Somatic sensations are classified into three different physiological types :

1- Mechanoreceptive sensations which include tactile , pressure, vibration and kinesthetic sensations.

2- Thermoreceptive sensations.

3- Pain sensation.

1-Mechanoreceptive sensations

a-Touch (tactile) sensation

This is a sensation evoked from skin by non noxious stimuli. *بشئ غير ضار*

There are two types of touch :

1- Crude touch :

this is a poorly localized touch sensation and needs a relatively stronger touch stimulus.

The receptors are : hair end organs around the roots of hair.

Tested by stroking the skin by a piece of cotton while the person closes his eyes.

2- **Fine touch** : it is well localized and includes tactile localization, and tactile discrimination.

Tactile localization : this is the ability to localize a touched skin point while the eye are closed.

It is tested by touching the skin lightly with a marker pencil (charcoal pencil) and the subject is asked to touch the stimulated point by another pencil. The closer the two points to each other, the more accurate is the localization.

T. localization is more accurate if a given skin area is rich in receptors and if it is represented in a wide cortical area. It is more accurate in lips and finger tips than forearm and thighs.

Tactile discrimination (2-points discrimination) :

« Is the ability to distinguish two touch stimuli applied simultaneously to the skin as two separate points of touch. »

Compass test : the person closes his eyes during the test. The skin is touched at the same time with the two blunted points of a compass. The person is asked to state whether he felt one or two points of touch while both eyes are closed. The minimal distance between the two points at which discrimination occurs is determined.

Explanation :

For discrimination to occur, the afferent impulses from the two receptors stimulated by compass should reach two separate neurons in sensory cortex. Inaccurate discrimination occurs when such impulses reach the same neuron in CC. In a finger tip if the compass points are 2.3 mm apart, discrimination occurs because afferent impulses reach two separate cortical neurons. If the distance is less than 2.3 mm ~~at~~ no discrimination occurs because all touch receptors within this distance send impulses to one cortical neuron, thus, feeling the two compass points as only one. The discrimination is not similar all over the body. While it is 2.3mm for finger tips, it is about 70 mm for shoulders and thighs.

b-The pressure sensations

It requires a great amount of mechanical stimulus than that for touch.

Receptors : It is perceived mainly by the pacinian corpuscles and Ruffini's endings in both the skin as well as the s/c tissues.

It is tested with closed eyes where different weights are put on supported hand of the subject and he is asked to differentiate between them.

c-Vibration sense

It is due to repetitive stimulation of particular types of mechanoreceptors
example ; meissner's corpuscles and pacinian corpuscle.

It is detected by placing the base of vibrating fork on any bony prominence.

d- Kinesthetic sensations

These sensations arise from deep structures especially muscles and joints.
They inform the brain about the orientation of the various parts of the body with respect to each other as well as the movement of joints. They include :

1-sense of position :

This is the sensation of the position of different parts of the body with respect to each other.

Its receptors include muscle spindle and Golgi tendon organ and Ruffini's endings.

It can be tested by putting one of the patients limbs in an abnormal position while his eyes are closed, then ask the person to put the other limb in a similar position.

2-sense of movement:

This is the sensation of movement of joints.

Its receptors are located around the joints (pacinian and Golgi tendon organ receptors). It can be tested by passively moving one of the patients fingers or toes by the examiner while his eyes are closed and ask him about the feeling of movement as well as the rate and direction .

II- Thermoreceptive sensations

There are two types of thermal sensations :

- (1) Cold sensations (receptors are Krauser's end bulbs) and Warm sensations (receptors are Ruffini's end organs).
- (2) Recently both sensations are taught to be mediated by free nerve endings.
- (3) They discharge in type c nerve fibers.
- (4) They are stimulated more by changes in temperature than by constant temperature.

Temperature receptors :

Cold receptors : are moderately adapting receptors. They discharge impulses at 10°C and stop discharging completely at 35°C. Cold receptors also discharge briskly (for a short time) at 45-50°C.

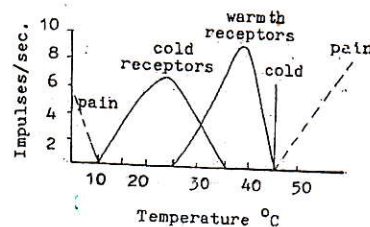
↓ Paradoxical cold sensation.

Warm receptors : are more rapidly adapted than cold receptors. They discharge impulses at 25°C and stop completely at 45°C.

NB:

At temperatures below 10°C and above 45°C, thermoreceptors stop discharging and the thermosensitive pain receptors are stimulated.

At zero degree all receptors stop discharging, so excessive cooling of the skin can be used as a method of local anesthesia.



Paradoxical cold sensation :

When the skin is suddenly exposed to a hot temperatures of about 45-50°C as on taking a hot shower, a temporary sensation of cold is first felt. This is called paradoxical cold sensation. It is due to :- ** both the brisk stimulation of cold receptors at this temperature , **as well as their greater number than warmth receptors.

Both hypertensive and cardiac patients are advised to avoid to take excessive cold or hot showers because very cold shower cause VC while excessive hot shower cause tachycardia which is dangerous since it

increases the work of already weak hearts. These patients must have baths nearly equal to body temperature (37C).

III-Pain sensation

Pain is an unpleasant sensation that is characterized by :

- 1- It is protective for the body since it initiates the withdrawal reflex.
- 2- It is widely distributed, presented in the skin, deep structures, and deep viscera.
- 3- Its adequate stimulus is not specific. It can be produced by mechanical, thermal, or chemical stimuli provided they are noxious (lead to tissue damage).
- 4- It is mostly non adapting sensation.
- 5- It is perceived at both cortical level as well as the thalamic level.

Pain receptors (the nociceptors) :

These are specific naked free nerve endings that are present at termination of small myelinated delta A and unmyelinated type c fibers.

The threshold for excitability for these receptors is high (the stimulus must be strong to cause damage), so they are called nociceptors.

Mechanism of stimulation of pain receptors :

It is assumed that chemical substances as bradykinin, serotonin, histamine, acids and proteolytic enzymes are released from cells damaged by painful stimulus and that these substances activate the nociceptors and cause the pain sensation.

Types of pain :

- 1-cutaneous pain: produced by stimulation of pain receptors in skin.
- 2-deep pain : results from stimulation of pain receptors in deep structures as skeletal muscle and joints.
- 3-visceral pain : arising from the internal viscera.

4-referred pain

Cutaneous pain

Fast and slow pain:

Pain from skin is carried by two types of afferent fibers having different velocities. Because of this double innervation, a sudden painful stimulus gives a double pain sensations, a fast pricking pain and a slow burning pain.

Differences between fast and slow pain

	Fast pain	Slow pain
site	<u>Only skin</u>	<u>Skin, deep tissues, and viscera.</u>
quality	<u>Pricking (sharp or acute)</u>	<u>Burning (aching or chronic).</u>
perception	Within 0.1 sec after stimulus application.	One sec or more after stimulus application.
stimulus	Mainly mechanical&thermal stimuli	<u>All but mainly chemical.</u>
localization	<u>Well localized</u>	<u>Diffused or poorly localized.</u>
Afferent n.	A-delta nerve fibers	C nerve fibers
Centre in NS	<u>Mainly cerebral cortex</u>	<u>Mainly thalamus.</u>

II- Deep pain

It arises from structures deep to skin like muscles, joints, ligaments, and the periosteum of bones. It has the following ch.chs :-

- 1- It is slow pain that is conducted by thin nonmyelinated afferent C fibers.

- 2- It is diffuse (non localized) and dull pain.
- 3- It is often associated with autonomic effects like bradycardia, hypotension, nausea and vomiting.
- 4- It is usually referred to other sites.
- 5- It may cause somatic reflexes like reflex contraction in the overlying muscles.
- 6- It may be caused by trauma, muscle ischemia or spasm, arthritis, and bone fracture.

III-Visceral pain

There are few pain receptors in most viscera than cutaneous pain receptors, so highly localized type of damage rarely causes severe pain, however, any stimulus that causes diffuse stimulation of pain nerve endings throughout the viscus causes severe pain for eg; ischemia caused by occluding blood supply to a large area of gut stimulates many diffuse pain fibers simultaneously leading to extreme pain.

Causes of visceral pain :

1-visceral ischemia, due to thrombosis, causes acidic metabolites to accumulate like lactic acid, also degenerative products such as bradykinin or proteolytic enzymes released from damaged tissue stimulate pain nerve endings and cause pain.

2-Chemical stimuli for example gastric acidic juice leakage from a perforated peptic ulcer leads to digestion of a large portion of visceral peritoneum, thus stimulating a wide area of pain receptors and causes severe pain.

3-overdistension of a hollow viscus eg; extreme overfilling of urinary bladder, causes pain because of overstretch of tissues, and also collapse of blood vessels encircling the viscus leading to ischemic pain.

4-Spasm of hollow viscus eg; spasm of a portion of the gut, a bile duct or ureter. Pain occurs by the same above mechanisms. Pain here is usually cramping or colicky in nature like in uretric colic and constipation.

IV: Referred pain

This is the pain that is felt away from its original site.

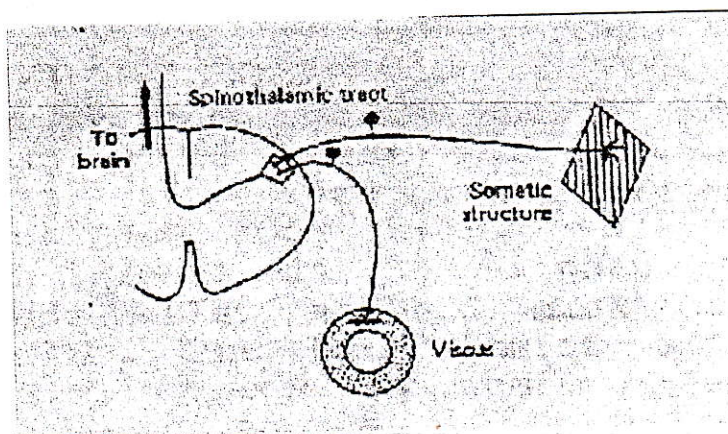
It is most common with visceral and deep pains but cutaneous pain is not referred.

Examples of referred pain:

- 1- Cardiac pain : usually referred to left shoulder and inner side of the left arm.
- 2- Pain of cholecystitis is usually referred to the tip of the right shoulder.
- 3- Inflammation of the appendix: pain from inflamed appendix is referred to an area around the umbilicus.
- 4- Pain of uretric colic is referred to the inguinal area and testicles.

Mechanism of referred pain (the convergence-projection theory):

Pain impulses from skin and diseased viscus are transmitted by two afferent neurons which converge on the same neuron of the spinothalamic tract, further convergence occurs at the thalamic and sensory cortex levels. Visceral pain is projected to the skin area because the sensory cortex is used to receive dominant signals from somatic structures but rarely from the viscera.



Convergence-Projection theory (Mechanism of referred pain)

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The sensory pathways (Ascending tracts)

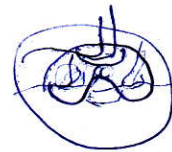
The nervous pathways conducting the impulses to the higher levels of the CNS are called the **ascending tracts**.

Almost all sensory information from the somatic segments of the body enters the spinal cord through the dorsal roots of the spinal nerves. However, from the entry point into the cord and then to the brain, the sensory signals are carried through one of two alternative sensory pathways:

(1) the **dorsal column–medial lemniscal (DCML) system** or

(2) the **anterolateral system**. These two systems come back together partially at the level of the thalamus

The main ascending tracts are :



The lateral spinothalamic tract :

-This tract transmits pain, temperature, and sexual sensations.

-First order neurons (include afferent nerves which have their bodies in the dorsal root ganglia) enter SC via the dorsal roots, ascend or descend a few segments, then terminate around small cells in the posterior horn called substantia gelatinosa of Rolandi.

-2nd order neurons consists of SG cells and their axons that cross to the opposite side close to the central canal, then ascend in the lateral column of SC and then in the brain stem to terminate in the ventrobasal complex of thalamus.

- 3rd order neurons start from the posteroventral nucleus of the thalamus and terminate in somatic sensory area I and II in cerebral cortex.

The ventral spinothalamic tract :

This tract transmits *crude touch sensations*, consists of :

-First order neuron consists of afferent nerve fibers that enter the SC via dorsal roots, ascend or descend few segments then terminate on large cells in the posterior horn.

-2nd order neurons consists of posterior horn cells and their axons which cross to the opposite side in the anterior commissure and ascend to the thalamus in the anterior columns of the SC.

-3rd order neurons start in thalamus, pass in sensory radiation in the posterior limb of internal capsule and terminate in somatic sensory areas of cerebral cortex.

Dorsal column medial lemniscal system (the Gracile and cuneate tracts) :

These tracts carry fine touch (tactile localization & tactile discrimination), vibration sense, position and fine pressure senses.

the nerve fibers entering the dorsal columns of SC pass uninterrupted up to the dorsal medulla, where they synapse in the dorsal column nuclei (the gracile and cuneate nuclei). From there, second-order neurons decussate immediately to the opposite side of the brain stem and continue upward through the medial lemnisci to the thalamus. From the ventrobasal complex, third-order nerve fibers project, mainly to the postcentral gyrus of the cerebral cortex, which is called somatic sensory area I and II.

Gracile tract carries sensations from lower part of the body while cuneate tract from the upper part of the body.

Differences between DCMLS and anterolateral system

	<u>DCMLS</u>	<u>Anterolateral system</u>
<u>course</u>	2nd order neurons include gracile and cuneate neurons and their axons.	2 nd order neurons include SG cells and their axons.
<u>Composition</u>	Composed of large, myelinated nerve fibers that transmit signals to the brain at velocities of <u>30 to 110 m/sec</u>	Composed of smaller myelinated fibers that transmit signals at velocities ranging from a <u>few meters</u> per second up to <u>40 m/sec</u>
<u>Types of sensations transmitted</u>	limited to discrete types of mechanoreceptive sensations (<u>fine pressure</u> , <u>fine touch</u> , <u>vibration</u> , <u>position sense</u>).	transmit a broad spectrum of sensory modalities— <u>pain</u> , <u>warmth</u> , <u>cold</u> , and <u>crude tactile sensations</u>

Somatic sensory areas of cerebral cortex

Human cerebral cortex is divided into two large hemispheres, each contains 5 lobes (frontal, parietal, temporal, occipital and limbic lobes). The surface of each lobe is formed of elevations called gyri separated by depressions called sulci. Each gyrus is divided into areas identified by numbers called Brodman's areas.

A large central fissure also called central sulcus extends horizontally across the brain and separates the frontal and parietal lobes. **The sensory cortex lies behind the central fissure, occupying most of the parietal lobe and is divided into 3 main parts :**

1- somatic sensory area I (areas 1,2, and 3) :

this area is located at the postcentral gyrus, immediately behind the central sulcus in the parietal lobe.

Characteristics of somatic sensory area 1 :

- 1-it receives sensations from the opposite side of the body.
- 2-The body is represented in an inverted manner i.e the head is represented in the lower part while the legs lies in the upper part of the sensory area.
- 3-The area of representation of body areas are proportionate to the number of sensory receptors in that part and not to its size. For instance, the lips and fingers occupy a much greater area than that occupied by the trunk and lower part of the body.

Functions of somatic sensory area 1 :

It receives the following sensations :

Fine touch (tactile localization, tactile discrimination).

Discrimination of weights.

Vibration senses, sense of position and of movement of joints.

Discrimination of various grades of temperature.

2- somatic sensory area II (area 40)

Located behind the lower end of sensory area 1.

Characterized by :

Poor localization of the different parts of the body as compared with somatic sensory area I. Roughly the face is represented anteriorly, arm centrally and the leg posteriorly.

Functions

little is known about its function but it is thought to be the cortical centre for pain.

3- somatic sensory association area (areas 5&7) :

This area is located behind area S1 and above area SII. It receives signals from these areas as well as from various thalamic nuclei and visual and auditory areas.

Functions :

It is concerned with interpretation of sensations (understanding and giving meaning to them).

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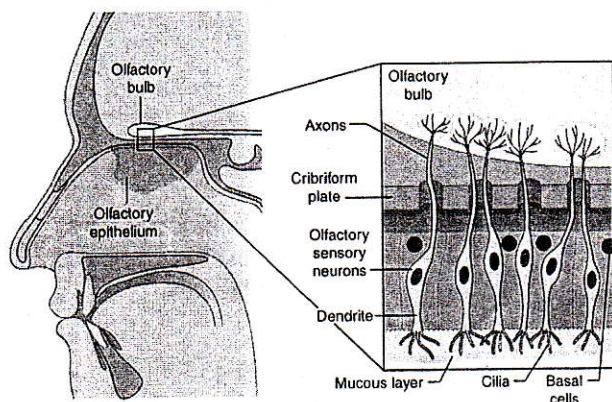
Physiology of smell (olfaction)

The olfactory membrane:

The olfactory mucous membrane is located at the roof of each nostril. Medially it folds down ward over the surface of the septum, laterally it folds over the superior turbinate and over a small portion of the upper surface of the middle turbinate. The membrane is constantly covered by mucous secreted by Bowman's glands.

The olfactory cells:

The receptor cells for smell sensation are the olfactory cells which are actually bipolar nerve cells derived originally from the CNS. There are 100 million of these cells in the olfactory epithelium interspersed among sustentacular cells. The mucosal end of the olfactory cell forms a knob from which 4-25 olfactory hairs project into the mucous that coats the inner surface of the nasal cavity. Their axons pierce the cribriform plate of the ethmoid bone and enter the olfactory bulb.



Stimulation of olfactory receptors :

These receptors respond only to substances that comes in contact with the olfactory epithelium and are dissolved in the thin layer of mucous that covers it. Therefore, odorants should be : *A- volatile. B- relatively highly water soluble and lipid soluble.*

The odorant substance on coming in contact with the olfactory membrane surface, first diffuses into the mucous that covers the cilia., then it binds with a receptor protein in the membrane of each cilium. On excitation of the receptor protein, adenylyl cyclase enzyme (attached to the inside of ciliary membrane) is activated which in turn converts ATP into cAMP. Finally cAMP activates Na^+ gated channels and cause them to open and allow large no. of Na^+ ions to enter into the receptor cell cytoplasm. Na^+ ions cause depolarization of cell membrane and excite the olfactory neuron and transmit action potentials into CNS by way of olfactory nerve.

The olfactory nervous pathway :

The axons of the olfactory receptor pierce the cribriform plate of the ethmoid bone and enter the olfactory bulb where they terminate in relation to the dendrites of 2 types of cells, the mitral cells and tufted cells, to form complex globular synapses called olfactory glomeruli. Other cells in the olfactory bulb include the granule cells (mostly inhibitory cells). The output efferent fibers that leave the olfactory bulb via the olfactory tract are mostly axons of the mitral cells. The axons pass posteriorly through the intermediate and lateral olfactory striae and terminate on the dendrites of pyramidal cells in the olfactory cortex.

NB: it should be noticed that unlike other sensations, no fibers in the olfactory nervous pathway pass through the thalamus.

Olfactory adaptation :

The olfactory receptors adapt about 50% in the first second after stimulation, thereafter they adapt very slowly. Yet from our experience we know that smell sensation adapt completely within a minute or so after entering a strongly odorous atmosphere so it is thought that additional olfactory adaptation may occur in CNS.

Mechanism of CNS adaptation:

« In addition to the afferent input from the olfactory mucous membrane, the olfactory bulb also receives afferent inputs in a backward direction (centrifugal fibers) from both the ipsilateral and contralateral anterior olfactory nucleus and the nucleus of diagonal band that terminate mostly at the **granule cells**. These cells in turn inhibit other cells in olfactory bulb. Such inhibitory feedback pathway may explain how olfactory adaptation takes place. »

Physiology of Taste (Gustation)

There are four types of tongue papillae :

The circumvallate papillae arranged in a v shaped area at the back of the tongue.

The fungiform papillae located near the tip of the tongue.

The foliate papillae located at the lateral edges of the tongue.

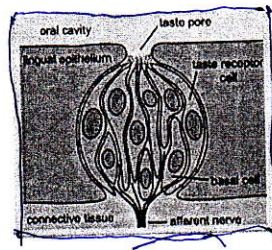
The filiform papillae located at the anterior dorsum of the tongue but contain no taste buds.

The taste receptors :

These are the taste buds that are found on 3 types of tongue papillae. Additional taste buds are located on the palate, tonsillar pillars, and proximal esophagus.

except filiform

Each taste bud is an ovoid body, formed of supporting cells called sustentacular cells and taste cells. From the tip of each taste cell several microvilli or taste hairs protrude into the taste pore to approach the mouth cavity.



Stimulation of the taste buds :

These receptors respond only to the dissolved substances in the saliva. Taste substance first binds to a specific protein of the microvilli membrane and this cause depolarization of the receptor and initiates an action potential in the sensory neurons.

The type of receptor protein in the taste villus determines the type of taste that will be perceived. For salty and sour taste sensations, the receptor protein open Na and H ion channels in the apical membrane of taste cells. For sweet and bitter taste the receptor protein increases cAMP which cause intracellular changes that elicit taste signals.

Nervous pathway of taste :

First order neurons: these include the sensory nerve fibers that arise from the taste buds. Taste impulses arising from the anterior two thirds of the tongue travel in the chorda tympani into the facial nerve, while those arising from the posterior one third of the tongue travel via the glossopharyngeal nerve. Those from the base of the tongue and other parts of the pharynx via the vagus nerve. All sensory fibers unite in the medulla oblongata forming the nucleus of the tractus solitarius.

Second order neurons :

Start at this nucleus, cross the midline, join the medial lemniscus and ascend till terminating at the posterior ventral nucleus of the thalamus.

Third order neurons :

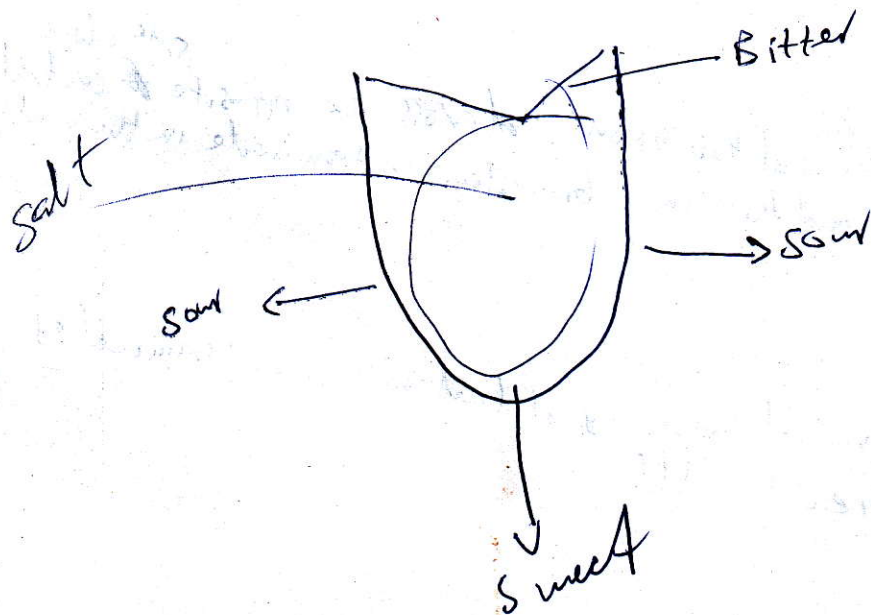
Arise from the thalamus, pass in the sensory radiation via the posterior limb of the internal capsule and terminate at the taste area of cerebral cortex in the lower part of the post central gyrus.

Taste modalities = types of taste sensations :

In man, there are four basic taste modalities :

- 1- **Bitter** : this is tasted at the back of the tongue. Mostly sensed by circumvallate papillae and is caused by quinine sulphate, strychnine, morphine, nicotine, caffeine.
- 2- **sour** : tasted along the edges of the tongue, sensed by foliate papillae. caused by H^+ ions of acids.
- 3- **Sweet** : tasted at the tip of the tongue, sensed by fungiform papillae, caused by sucrose, maltose, glucose, ketons, polysaccharides, and some alcohols.
- 4- **Salty** : tasted over the entire tongue . Caused by ionized salts.

Dr.Ghada Al-Qirshi



Luc: 4

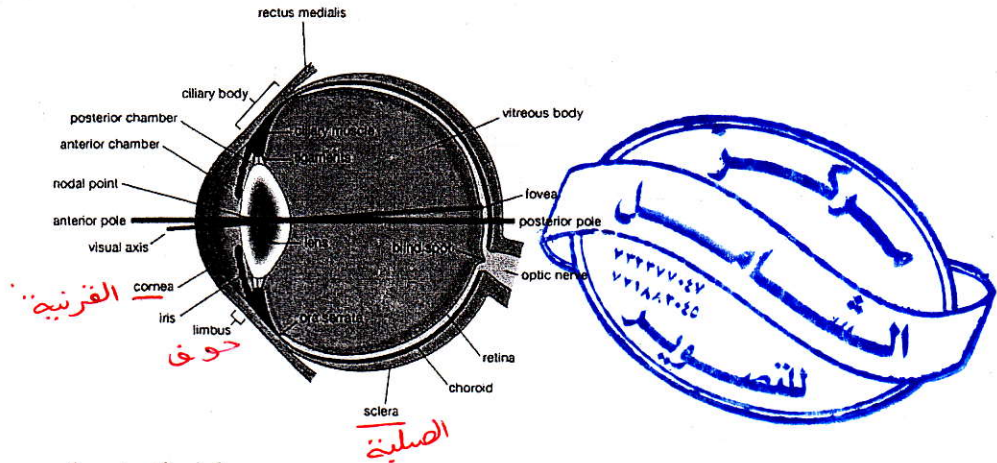
Trabecular meshwork: The fibrous basement membrane in the Angle between the Iris and the cornea-sclera Junction. Aqueous Humor exits the Anterior chamber of the eye through spaces in the trabecular meshwork and enters the venous sinus of sclera (the Canal of Schlemm).

Vision

The adult human eye is nearly globular (spherical) in shape, and consists of three coats and three chambers.

Extraocular Eye muscles:

- ① superior rectus muscle
- ② inferior rectus muscle
- ③ medial rectus muscle
- ④ lateral rectus muscle
- ⑤ superior oblique muscle
- ⑥ inferior oblique muscle.



(1) An outer fibrous (protective) layer

The posterior 5/6 of this layer is opaque and is called the sclera, it is protective to the eye and gives attachment to the extraocular muscles that move the eye ball.

The anterior 1/6 is transparent and called the cornea, Most of the cornea consists of the stroma which is composed of lamellae of collagen fiber that run parallel to the surface. The cornea is transparent and a vascular, it receives its oxygen and nutrients from tear film, and the aqueous fluid.

Causes of corneal transparency :

- 1- the collagen lamellae of the stroma are arranged regular and parallel to the surface.
- 2- absence of myelin sheath in the nerve fibers that supply the cornea.
- 3- absence of corneal blood vessels .
- 4- Corneal dehydration : The cornea contains mucopolysaccharides which absorbs much water which leads to corneal hydration and cloudiness of the cornea. However the aqueous humor and the tears are hypertonic relative to corneal tissue so they draw water from the cornea.

The junction where the cornea meet the sclera is called the limbus at which there is an important canal that drains the aqueous humor known as Canal of Schlemm.

(2) A middle vascular layer (the uveal tract)

uveitis

This layer consists of the iris and ciliary body anteriorly and the choroid posteriorly.

* Hypertonic : to a solution of higher osmotic pressure than other.

$$\begin{array}{r} 70 \times \\ 80 \\ \hline 5600 \end{array}$$

$$80 \frac{\text{ml}}{\text{kg}}$$

The uveal tract structures:

- ① Iris
- ② ciliary Body
- ③ Choroid

$$\begin{array}{r} 100 \times \\ 80 \\ \hline 8000 \end{array}$$

$$\begin{array}{r} 50 \times \\ 80 \\ \hline 4000 \end{array}$$

$$\begin{array}{r} 100 \times \\ 80 \\ \hline 8000 \end{array}$$

$$\begin{array}{r} 50 \times \\ 80 \\ \hline 4000 \end{array}$$

The iris: is a coloured partition in front of the crystalline lens that has a central round aperture (opening) called the pupil. It also contains two types of smooth muscle which control the size of the pupil :

- 1- Sphincter pupillae : which is a narrow circular band around the pupil. It is innervated by para sympathetic oculomotor fibers. Its contraction leads to pupillary constriction = miosis
- 2- Dilator pupillae : its fibers run radially blending with sphincter fibers. It is supplied with sympathetic nerves and its contraction causes pupillary dilatation = mydriasis.

Functions of the iris :

- It regulates the entry of light rays into the eyes through the pupil.
- It contains pigments which prevent light from entering the eye except through the pupil.
- Protective to the lens.
- It shares in drainage of aqueous.

The ciliary body is pyramidal in shape and contains ciliary muscle and ciliary processes.

Functions of ciliary body :

- 1- Ciliary muscle is essential for accommodation.
- 2- Ciliary processes secrete the aqueous humor into the posterior chamber.
- 3- It gives attachment to the suspensory ligament of the lens.

The choroid :

It is a vascular layer that provides blood supply and nutrients for retina.

It is rich in melanin which prevents light reflection inside the eye.

(3) An inner nervous layer (the retina).

Which contains the photosensitive receptors called rods and cones. It extends anteriorly and ends just behind the ciliary body at the ora serrata.

Chambers of the eye globe

(1) Anterior chamber

This chamber is lined anteriorly by the posterior corneal surface and posteriorly by the iris and anterior lens capsule. It is filled with a clear fluid called the aqueous humor.

Miosis: (lessening) abnormal contraction of the pupils, possibly due to irritation of the oculomotor system or paralysis of dilators. Pupillary contraction may occur after a stroke that affects the brainstem or after administration of drugs such as opiates or eyedrops that inactivate Acetyl cholinesterase.

(2) Posterior chamber

This chamber is lined anteriorly by the posterior surface of the iris, laterally by the ciliary body and posteriorly by the suspensory ligament and the lens. It also contains the aqueous humor.

(3) Vitreous space *vitreous*

It consists of fibrillar framework within which a transparent gel (vitreous humor) is found. The vitreous occupies about 4/5 the volume of the eye ball.

Functions of vitreous humor :

- Shock absorber.
- A refractive media of the eye.
- Supports the posterior surface of the lens.
- Holds retina in its place.

The aqueous humor

Is a clear fluid which fills both the anterior and posterior chambers of the eye.

It is produced by the ciliary processes of the ciliary body into the posterior chamber, then passes through the pupil into the anterior chamber. The fluid then flows toward the anterior chamber angle where it drains through a trabecular meshwork into the canal of Schlemm to the venous drainage of the eye.

Functions:

- *it gives nutrients to the non vascular structures (lens&cornea).
- *it maintains the intraocular pressure.
- *a refractive medium in the eye.
- *it's a route for removal of waste products from the eye.

The intraocular pressure (IOP)

The normal IOP is from 12-20 mmHg (average 15 mmHg).

It is kept fairly constant due to the balance between ciliary production and aqueous drainage. Clinically, it is measured by an apparatus called the tonometer

Glaucoma المياه الزرقاء

A serious condition that leads to blindness, in which IOP is markedly increased (up to 60-70 mmHg).

*normal
12-20 mmHg*

Tonometer

It occurs when the pathway that allows aqueous humor to drain via the canal of Schlemm is obstructed. Humor production continues and IOP rises.

Treatment of glaucoma :

Inducing pupilloconstriction by parasympathetic drugs (pilocarpine drops). This opens the canals and increase the outflow of aqueous humor so decrease IOP.

Giving drugs that decrease secretion of aqueous humor eg diamox

Surgery if the above medical treatments fail.

The lens

The crystalline lens of the eye is a biconvex transparent structure that is suspended to the ciliary body by the suspensory ligament. During rest, its posterior surface has a greater curvature than its anterior surface.

Convex lenses converge parallel rays to a focal point , the distance of which from the nodal point (central part of the lens) is called the **focal length**. The focal length depends on the power of the lens (the greater the power of the lens, the shorter will be its focal length and vice versa).

The diopter : This is the unit of the power of lenses. The power of a certain lens in diopters equals the reciprocal of its focal length in meters. For example the power of a lens having a focal length 0.1 meters = 10 diopters.

Histologically, the lens is formed of a transparent elastic capsule, a single layer of epithelium lining the anterior capsule and a lens substance made up of regularly arranged fibers and interstitial cement material.

Causes of lens transparency :

- 1- Absence of blood vessels and nerves.
- 2- The uniform arrangement of the different lens fibers.
- 3- The nearly equal refractive indices of the lens constituents.

Functions of the lens:

-An important refractive medium providing about 1/3 of the total refractive power of the eye optical system at rest. Its refractive power inside the eye is 20 diopters.

-Its elasticity allows it to be more spherical which is essential for accommodation process.

-Protective to the retina because it absorbs a considerable amount of UV rays entering the eye.

Cataract :

This is a condition in which the lens loses its transparency and becomes opaque and whitish as a result of denaturation of its proteins.

Causes:

- Exposure to high temperatures or x-ray radiations → denaturation of lens proteins followed formation of opaque areas.
- Diabetes mellitus : secondary to disturbances of glucose metabolism in the lens.
- Old age (senile cataract).

Treatment :

Surgical removal of the opaque lens and supplying a convex lens of suitable power (in form of either glasses, contact or implanted lenses).

Accommodation (the near reflex)

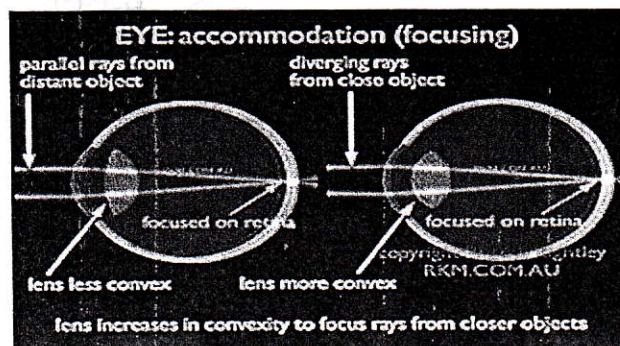
A process by which optical system of the eye is adjusted to see near objects clearly.

Normally, during distant vision, the ciliary muscle is relaxed and parallel rays, those coming from objects placed more than six meters away from the eye, are brought into sharp focus on the retina. This condition is normal and called emmetropia.

Light rays coming from objects placed at nearer distances than 6 meters from the eye are divergent and they form a focus behind the retina. Accordingly, these objects are indistinct and in order to see them clearly their images should be brought on the retina. This is produced through a process of accommodation (near reflex).

Mechanism of accommodation:

The blurred vision stimulates the eye to increase its refractive power to see near objects clearly. Contraction of both the circular and radial fibers of the ciliary muscle pulls the whole ciliary body forward and inward. This leads to relaxation (slackening) of suspensory ligaments so the lens assumes a more spherical and convex shape thus increasing its refractive power and shifting the image toward the retina.



it is a process by which the eye system is adjusted to see near objects clearly
"Near reflex"

Presbyopia (old-age sight) النظر الشيخوخي

This is a physiological decrease in the power of accommodation that occurs in old age.

It usually starts at the age of 40-45 years and increases with age.

The crystalline lens loses its elasticity and gets harder due to gradual loss of its fluid state of lens proteins; and the person can not see near objects eg. reading, threading a needle become difficult.

Treatment is by convex lens for near vision.

Errors of refraction

1- Emmetropia :

This is the normal state of refraction of the eye. Parallel rays from a distant object are in sharp focus on the retina without accommodation.

2- Hypermetropia (far sightedness) :

An optical defect in which parallel rays striking the eyes come to a focus behind the retina → blurred retinal image.

Causes : too short eye ball, too weak lens

Treatment : convex lens

3- Myopia (near sightedness) :

An optical defect in which parallel rays striking the eye come to a focus in front of the retina → blurred image.

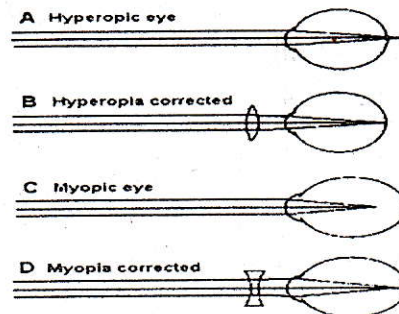
Causes : too long eye ball, too great lens power.

Treatment : concave lens

4- Astigmatism

An optical error in which the curvature of the cornea is not uniform (irregular). Light rays in different meridian are refracted to a different foci leading to a blurred image.

Treatment is by using cylindrical lens.



Hypermetropia

Myopia

Presbyopia

Emmetropia

Astigmatism

Luci:- 5

Physiology of Hearing

Sound : is vibrations of air moving away from the source in all directions.

The frequency or number of vibrations/sec is referred to as Hertz. The human ear can perceive sounds over a wide range of frequencies from 16 Hz to 20000 Hz (best range 1000-3000 Hz).

Structure of the human ear : Consists of three parts:

1- External ear includes :

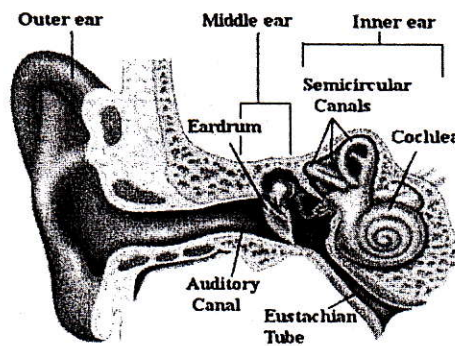
- The ear pinna (auricle) which collects and directs sounds toward EAM.
- The external auditory meatus (EAM) which is a narrow channel 2.5 cm in the adult that conducts the sound waves inward to the tympanic membrane.
- The tympanic membrane (ear drum) is cone-shaped and is composed of both circular and radial fibers. It acts as a resonator which reproduces the vibration of sound source. It also serves as a barrier to shelter the delicate contents of the middle ear.

external auditory meatus

2- Middle ear :

This is an air-filled chamber in the temporal bone. It connects to the nasopharynx by the Eustachian tubes. It contains the following structures :

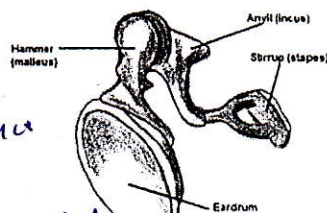
- three small bony ossicles called, the malleus; the incus; and the stapes.



The handle of malleus is attached to the inner surface of the tympanic membrane and it transmits vibrations to the incus. The incus transmits them to the stapes. The stapes footplate inserts to and is firmly attached to the oval window of the inner ear by annular ligaments.

What is the function of ear drum?

- 1- acts as a resonator which reproduces the vibration of sound source.
- 2- serve as a barrier to shelter the delicate contents of the middle ear.



Functions of the middle ear :

1-Impedence matching by the ossicular system : *القصور الذاتي*

The inner ear is filled with fluid that has a high inertia and is difficult to move compared with air. The middle ear has the ability to transmit sound waves to the inner ear with sufficient force to overcome the inertia of the fluid contents. This process is called impedance matching.

Mechanism :

1-The ossicular system forms a lever that increases the force of movement of the stapes by 1.3 times. Sound waves vibrate eardrum, the malleus is attached to and moves with the eardrum, the incus amplifies the movement.

2-The fact that the surface area of the eardrum (55mm^2) is about 17 times greater than that of the footplate of the stapes (3.2mm^2) amplifies the sound pressure at the oval window about 22 times which allow sound to be transferred to the inner ear with sufficient force to overcome the inertia of the fluid in cochlea.

2-Damping (attenuation reflex):

This is the reflex contraction of both tensor tympani and stapedius muscles in response to excessively loud sounds. The strong contraction of tensor tympani ms causes excessive stretch of the tympanic membrane which decreases its vibrations, while the simultaneous contraction of both muscles cause the ossicular system to be more rigid which greatly reduce ossicular conduction.

Importance : it protects the cochlea from injury by strong sound vibrations.

The Eustachian tubes (auditory tubes) :

These tubes connect the middle ear to the nasopharynx and (they are essential for equalization of pressures at the two sides of the ear drum.)

Normally, they are kept closed at their pharyngeal ends to prevent conduction of talking and breathing sounds to the middle ear which decreases the auditory acuity. *الحدوة*
However, the tubes normally temporarily open during swallowing, chewing, and yawning allowing free communication between the middle ears and the nasopharynx which always re-equalize the pressure at the two sides of the ear drum.

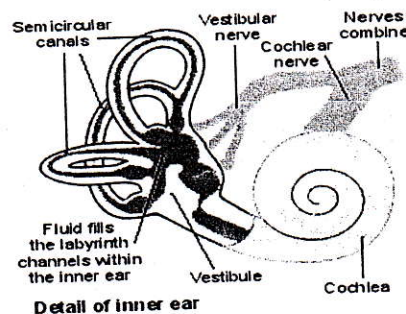
تأثير
In common cold, the tubes are closed for a long time by inflammation and exudate, the air in the middle ear will be gradually absorbed and the produced negative pressure will suck the ear drum inwards leading to excessive stretch which leads to severe pain and decreases the auditory acuity so the patient may temporarily suffer partial deafness. *الحدوة*

*What is the function of the Eustachian tubes?
They are essential for the equalization of pressure on both sides of the ear drum*

During ascending in plane : the atmospheric pressure is decreased and the tubes open automatically allowing air in the middle ear cavities to go out decreasing the pressure within the middle ears and an equal pressure is maintained at both sides of the ear drum.

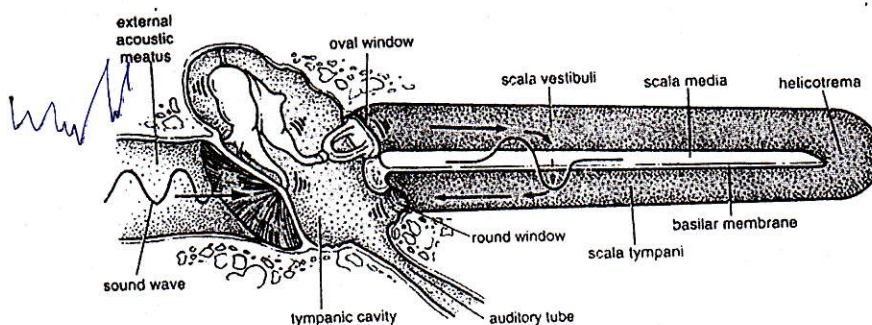
During descending in plane : the atmospheric pressure increases and this would lead to rupture of the ear drum. Therefore, during the descent of airplane one should swallow periodically to open the Eustachian tubes, allowing air to enter the middle ears and increase pressure inside the middle ear, so an equal pressure will be maintained at both sides of the ear drum.

3-The inner ear (the cochlea) :



The **cochlea** is a long coiled tube like a snail shell containing 3 fluid-filled chambers. The 3 chambers are called; the scala vestibuli; scala media; and scala tympani. Both scala vestibuli and scala tympani are filled with perilymph (a fluid similar to plasma) and are physically connected by a small opening called the helicotrema at the apex of the cochlea. At the base of the cochlea, the scala vestibuli ends at the oval window which is closed by the footplate of the stapes while the scala tympani ends at the round window which is closed by a flexible secondary tympanic membrane.

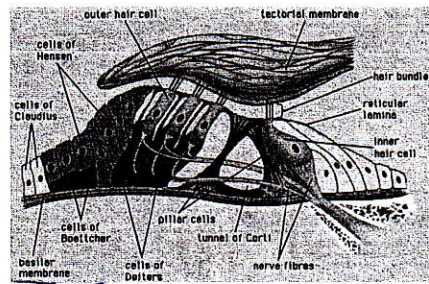
The centre chamber, the scala media, is separated from scala vestibuli by the Reissner membrane or (vestibular membrane) and from scala tympani by the basilar membrane. It is filled with endolymph (a K^+ rich fluid) secreted by a vascular area (stria vascularis) at the wall of the middle ear. The scala media contains the organ of Corti which is the auditory sensory organ.



The organ of Corti :

It lies on the basilar membrane. It is formed of a sheet of auditory receptor cells which rest on the basilar membrane. Two sets of hair cells (the auditory receptors) can be distinguished : the inner hair cells no 3500 arranged in one row, and 12,000 outer hair cells arranged in three rows. The inner hair cells are densely innervated by sensory neurons whose axons form the cochlear nerve. The upper ends of the hairs pierce a flat plate called the reticular lamina which is supported by the rods of Corti to the basilar membrane.

A sensory stereocilia project out from the hair cells at their apical surface. The tips of stereocilia are embedded in a gelatinous tectorial membrane which lies over the cells like a blanket.



Mechanism of Hearing

1-the pinna collects sound waves and directs them toward the EAM.

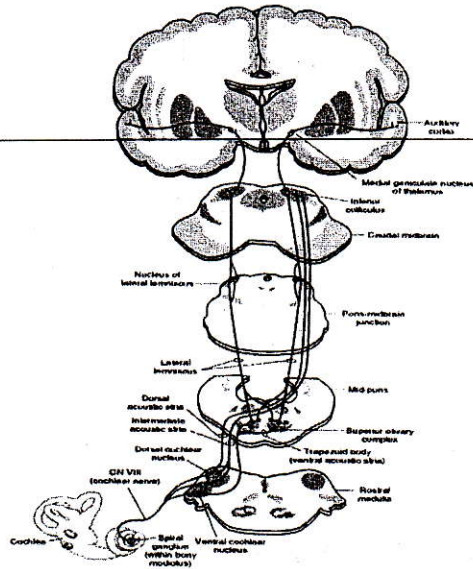
2-sound waves cause vibrations of the tympanic membrane.

3-tympanic membrane movements are transmitted and amplified by the bony ossicles of the middle ear to the oval window via the footplate of the stapes.

4-the movement of the footplate of the stapes lead to displacement of the perilymph in the scala vestibuli, the motion of this fluid moves the vestibular membrane which moves the endolymph in the s.media and causes the basilar membrane to move in a pattern determined by the frequency and intensity of the sound waves.

5-movement of the stapes inward causes a downward displacement while its movement outward causes an upward displacement of the basilar membrane. In both conditions a shearing motion occurs between the tectorial membrane and the reticular lamina leading to bending of the hair cilia of the hair cells thus opening K⁺ gated channels and allowing K⁺ ions to flow inside hair cells, which produce a receptor potential that initiates impulses in the cochlear nerve.

auditory pathway



Nerve impulses are transmitted from the cochlea to the auditory areas in the cerebral cortex via 5 neurons which include the following :

First order neurons

These are afferent nerve fibers in the cochlear nerve; the peripheral branch of which transmits nerve impulses from the hair cells of the organ of Corti. The cochlear nerve enters the brain stem at the upper border of the medulla oblongata then it divides into two branches which relay at the dorsal and ventral cochlear nuclei.

Second order neurons :

These arise from both cochlear nuclei and relay in the superior olivary nucleus and trapezoid nuclei at both sides.

Third order neurons :

These arise from the superior olivary and trapezoid, ascend in the lateral lemnisci of both sides and relay in the midbrain at both inferior colliculi.

Fourth order neurons :

These arise from the inferior colliculi and relay at the medial geniculate bodies of the thalamus.

Fifth order neurons :

These arise from the medial geniculate bodies and pass via the auditory radiations in the posterior limbs of internal capsules to reach their destination at the auditory cortical areas in the upper part of temporal lobes of the c. cortex at both sides.

Dr.Ghada Al-Qirshi

The retina

The retina is a nervous structure forming the inner layer of the eye. It contains the visual receptors called the rods and cones

Structure of the retina :

Histologically, the retina is formed of 10 layers. The most important include:

- 1-the pigment epithelium which lies next to the choroid.
- 2-the layer of rods and cones which are the end organs of vision.

The pigment layer of the retina :

This is the first layer of retina lying next to the choroid and it is rich in melanin.

Melanin

Functions : - it absorbs the light rays that are not absorbed by the photoreceptors thus preventing their reflection back on the retina which leads to blurring of vision.

2-it stores considerable amounts of vitamin A which plays an important role in retinal function.

Regions in the retina :

1-The optic disc (the blind spot) :

This is the site where the optic nerve fibers leave, and the central retinal artery enters the eye ball. It is a circular area having a diameter about 1.5 mm, located medial to the posterior pole of the eye. It contains only nerve fibers but no photoreceptors so it can not perceive light so it is called physiological blind spot.

Botulinum toxin

2-The macula lutea (yellow spot) and the fovea centralis :

The macula lutea is a yellowish shallow depression 1mm lateral to the optic disc, nearly at the centre of the retina. The centre of the macula is called fovea centralis (0.4 mm). it contains only cones and is capable of acute and detailed vision.

Causes why fovea has a maximum degree of acute vision :

Since the layer of rods and cones is the outer most layer in the retina, light rays have to pass through the various layers of the retina before reaching these photoreceptors, which would decrease the visual acuity, however, this occurs minimally because :

- 1- It contains only densely-packed cones.
- 2- It contains no blood vessels which increases the visual acuity.
- 3- In the fovea, the retina is thin due to pulling aside of other retinal layers. This allows light rays to reach the cones directly which increase the visual acuity.
- 4- Each foveal cone is connected to a single optic nerve fiber i.e has a private pathway to the cerebral cortex which allows visual acuity.

- 5- The pigment layer of the retina is highly developed in the foveal region which prevent light reflection and increase visual acuity.

The photoreceptors (rods and cones):

These are the photoreceptors of the retina. They contain specific photosensitive pigments which are chemically changed on exposure to light and such changes initiate signals (action potentials) in the optic nerve fibers.

They are two types :

Rods : these are sensitive to dim light and are responsible for night or scotopic vision.

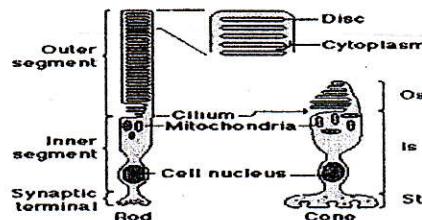
Cones : these are sensitive to bright light and are responsible for day or photopic vision and colour vision.

Structure of photoreceptors :

Each rod or cone is formed of an outer segment and an inner segment connected with each other by the neck.

The outer segment contains transverse discs containing photosensitive pigment. In rods the discs are separated from the cell membrane and contain rhodopsin. In cones the discs are formed by infoldings of the cell membrane and contain the 3 colour pigments. The inner segment is rich in mitochondria which provides energy for the photoreceptor function.

Processes from the rods and cones synapse with the dendrites of bipolar cells, the axons of which synapse with the dendrites of the ganglion cells. The axons of these collect and form the optic nerve fibers which leave the eye at the optic disc.



Differences between the rods and cones

	Rods	Cones
Number	120 million in each human retina .	6 million in each human retina.
distribution	Mostly at the periphery of the retina, few in the centre, <u>absent in fovea centralis</u> .	Mostly at the centre of the retina, few in the periphery, fovea centralis contains only cones.
function	Extremely sensitive to dim light	Sensitive to bright light so it is

	so it is responsible for Scotopic or night vision.	responsible for photopic or day vision and colour vision.
--	--	---

Photochemistry of vision :

-The photosensitive pigments are made up of a protein called opsin and a carotenoid pigment called retinene or retinal (an aldehyde form of vit A).

-The pigment in rods is called rhodopsin. its protein part is called scotopsin and its retinene molecule is in 11-cis form (curved molecule).

-The three cone colour pigments are almost structurally similar to rhodopsin except that its protein part is slightly different and called photopsin.

Rhodopsin-Retinal Cycle

When rhodopsin is exposed to light, it is immediately decomposed. The only action of light is to change the shape of 11-cis reinene, converting it into all-trans isomer (which is a straight molecule). The resulting compound is called bathorhodopsin (extremely unstable). It is rapidly converted to lumirhodopsin and this inturn is rapidly converted to metarhodopsin I then metarhodopsin II and finally complete separation of all-trans retinene from opsin.

NB: Metarhodopsin II initiates the electric changes in rods for this it is called **activated rhodopsin**.

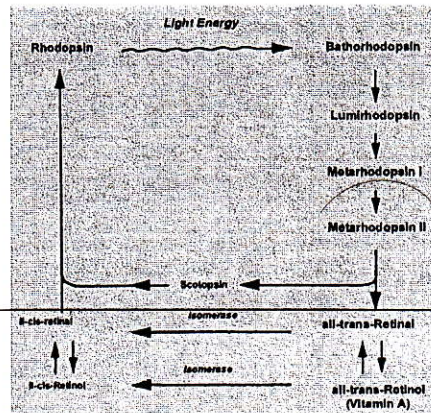
In the dark : rhodopsin reformation

Since the 11-cis retinene1 is the only form that can bind to scotopsin, the all-trans retinene is first reconverted to 11-cis form (catalyzed by the enzyme retinal isomerase) which automatically combines with scotopsin to form rhodopsin.

Role of vitamin A in rhodopsin formation

There is a second chemical route by which all-transretinal can be converted to 11-cis retinal. This is by conversion of all transretinal into all transretinol (a form of vit A) by the enzyme dehydrogenase. the latter is then converted to 11-cis retinol by isomerase enzyme which finally converted into 11-cis retinal by alcohol dehydrogenase and this combines with scotopsin to form rhodopsin.

Vitamine A is always present in the rod cytoplasm and also is stored in the pigment layer of the retina, so it is always available to supply new retinal when required to form more rhodopsin.



Rhodopsin-Retinal Cycle

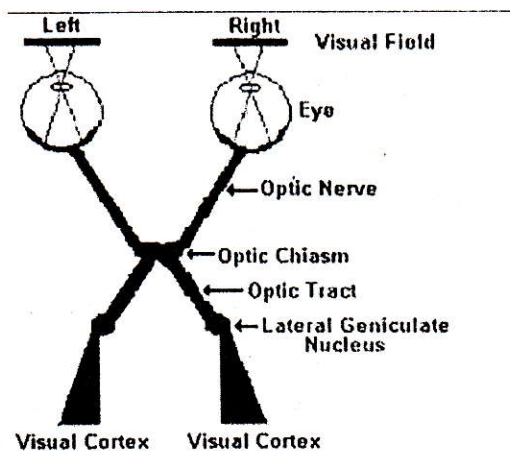
Excitation of visual receptors :

Metarhodopsin II decreases the rod membrane conductance for Na ions in the outer segment, while continually pumps Na from inner segments to the outside leading to hyperpolarization and initiation of nerve signals unlike other sensory receptors.

The Visual Pathway

Each half of the retina receives light rays from the opposite side of the visual field i.e. an object placed in the temporal (lateral) side of the visual field projects its rays to the nasal (medial) half of the retina and vice versa.

Visual impulses from the photoreceptors first stimulate the bipolar cells of the retina which in turn stimulate the ganglion cells, the axons of which form the optic nerve. The optic nerves meet at a structure called the optic chiasma. Here the nasal fibers cross the midline and join temporal fibers from the contralateral eye to form the optic tracts that converge on the lateral geniculate nucleus of the thalamus. Nerve impulses are then transmitted from the thalamus via the optic radiations to the primary visual cortex in the occipital lobe for analysis and interpretation.



Effect of lesions in the visual pathway

Importance of their study :

Lesions of the visual pathways produce ch.ch changes in the visual fields. By studying these changes the site of brain lesion can be detected.

Unilateral lesion in the optic nerve :

Leads to **blindness** in the corresponding eye (all retinal fibers are destroyed).

Lesions in the central part of the optic chiasma :

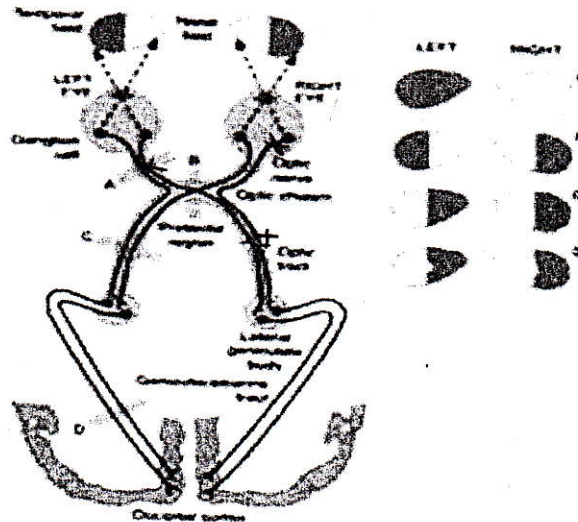
These are usually due to anterior pituitary tumors. They lead to **Bitemporal hemianopia** = **heteronymous hemianopia** (loss of vision in the temporal parts of the visual fields of both eyes), because crossing nasal fibers of both retinae are injured.

Optic tract lesion :

Destroys fibers from the temporal half of the retina on the same side and nasal half on the opposite side. So there is loss of the nasal field on the same side and the temporal field on the opposite side. For example injury of the left optic tract produces blindness of the right half of each field. This is called **homonymous hemianopia**.

Lesion of the lateral geniculate body or optic radiation on one side produces homonymous hemianopia.

Unilateral complete destruction of the visual cortex produces **homonymous hemianopia**.



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